5 Risk Characterization

Characterizing potential ecological risks posed by commercial traffic on the UMR-IWW System, the third step in the risk assessment process, resulted from the integration of the ecological models for impacts on fish with the results of the exposure analysis that characterized the magnitude of entrainment.

Potential impacts on or risks to fish larvae posed by commercial vessels were assessed using the CEM model (Boreman et al. 1981). The CEM model estimates the number of newly hatched fish larvae that are drawn through and subsequently killed by the propeller jet of commercial vessels traversing each pool on the UMR-IWW System during the spawning season. The results of the entrainment mortality calculations were extrapolated to estimates of future lost adults: EAL, RF, and PF. The EAL model (Horst 1975; Goodyear 1978) essentially compares the incremental entrainment mortalities to natural mortalities suffered by larvae and juvenile life stages. The RF model (Jensen 1990) addresses fish growth, in addition to simply extrapolating mortality, and may be important in evaluating the implications of larval entrainment of individuals that fail to recruit to commercial and recreational fisheries in the UMR-IWW System. The PF model (Rago 1984; Jensen et al. 1988) is analogous to the RF model, except that lost future biomass is estimated instead of individual recruits or adults. This model is important for assessing risks posed by commercial vessels on the biomass of important forage species.

This section of the ecological risk assessment examines the impacts of entrainment associated with percentage increases in commercial navigation for 30 species of fish in the UMR-IWW System. The assessment is large in scope, with results for each species for each month for each pool in the UMR-IWW System. Baseline calculations, estimated impacts, and their incremental differences were produced for each combination of species, month, and pool. The volume of model results precludes their detailed presentation in the body of this report. This section, therefore, focuses on the results for six selected species: emerald shiner, freshwater drum, mooneye, gizzard shad, channel catfish, and walleye. These species were selected on the basis of either recreational value (e.g., walleye), commercial importance (e.g., channel catfish), importance as a forage fish (e.g., gizzard shad) or status as threatened or endangered (e.g., mooneye). Results for the remaining species are summarized as computer files appended in CD-ROM distributed with this report (Appendix E). Instructions on how to run the fish entrainment models are also included in Appendix E.

This risk characterization addresses only the deterministic results of estimated impacts of increased navigation on larval fish entrainment. The results will provide brief examples of baseline impacts on channel catfish, that is, estimates of catfish entrainment mortality using the 1992 traffic data. The results of 25, 50, 75, and 100 percent increases in traffic intensity on channel catfish are presented subsequently. The estimated incremental impacts of the traffic scenarios on all six selected species are presented for Pool 13 using model results for either June or July. Finally, the incremental impacts on RF are summed across the entire UMR-IWW System for all six species as an example of how the results might be used to rank-order species in terms of potential impacts and risks. In all of the following tabulated results, the mean result refers to impacts estimated using the mean entrainment rates determined from the exposure assessment; the HQLS corresponds to the higher larval mortality rates produced by vessels with high entrainment rates traveling at slower speeds; and the LQHS identifies results obtained using the combination of lower entrainment rate and higher vessel speeds. These combinations appear to provide reasonable upper and lower values of estimated impacts.

Baseline Impacts

The results of using the 1992 baseline traffic to estimate impacts of "current" entrainment on channel catfish are listed in Table 8 for UMR Pools 4, 8, 13, 26A, and 26B and the IWW La Grange Pool; channel catfish impacts were also calculated for the remaining pools in the UMR-IWW System. The results demonstrate the potential magnitude of baseline entrainment on channel catfish for the month of July in each pool. Greatest estimated impacts resulted for Pool 26A, where as much as 11.5 percent of larval production might be entrained and killed by commercial traffic over the course of the month. The mean percentage entrainment values for these pools ranged from 0.388 percent in Pool 4 to 7.03 percent in Pool 26A. Lower bound estimates ranged from 0.184 percent to 3.81 percent.

It is important to note that assessing impacts depends in part on the selected ecological measure that characterizes the potential impact. For example, extrapolation of larval entrainment mortality using the RF model usually gives consistently lower numbers of lost recruits compared to extrapolation of the CEM estimates to lost future adults. The models are somewhat different in their extrapolations. While both derive from the same governing equation that extrapolates the longer term impacts of entrainment mortality, the EAL model extrapolates age-specific mortality rates incremented by larval entrainment over the entire life span of the species, as implemented in this assessment. The results of these EAL extrapolations to lost future adults can be interpreted in terms of future population dynamics. The RF model also extrapolates entrainment mortality, but develops an average mortality rate that is used to estimate losses to the recruit (i.e., age at sexual maturity) stage instead of the entire fish life span. The RF estimates are useful for interpreting entrainment mortality in terms of numbers of fish lost to the commercial or recreational fishery for the species. The EAL requires estimates of larval, young-of-the-year, and adult mortality

Table 8
Estimated Impacts for July 1992 Baseline Traffic on Channel Catfish

Pool	Larvae Killed	Percent of Pool Production	EAL #fish	RF #fish	PF tons
UMR 04					
Mean	2,190,000	0.388	523	738	242
HQLS	3,790,000	0.673	1,370	1,280	420
LQHS	1,030,000	0.184	129	349	115
UMR 08					
Mean	1,510,000	4.00	1,070	511	167
HQLS	2,520,000	6.66	1,810	852	277
LQHS	785,000	2.07	499	265	86.8
UMR 13					
Mean	2,820,000	2.72	1,910	954	312
HQLS	4,660,000	4.49	3,310	1,570	514
LQHS	1,500,000	1.44	838	506	166
UMR 26A					
Mean	28,000,000	7.03	19,900	9,470	3,090
HQLS	45,800,000	11.5	32,800	15,500	5,030
LQHS	15,200,000	3.81	98,900	5,130	1,680
UMR 26B					
Mean	32,700,000	4.04	21,600	11,100	3,620
HQLS	53,500,000	6.60	37,800	18,100	5,900
LQHS	17,700,000	2.18	9,450	5,970	1,960
IWW La Grange Pool					
Mean	914,000	0.543	642	309	101
HQLS	1,640,000	0.972	1,170	353	180
LQHS	395,000	0.235	230	134	43.7

Note: to convert tons to kilograms, multiple by 907.1847.

rates in this assessment. The RF model calculates an average mortality rate based on the growth characteristics of the recruit, which are often more easily obtained. If the models are integrated to the same time scale (e.g., fish life span) and the life stage-averaged mortality rates (i.e, EAL model) equal the average mortality rate (i.e, RF model), both models should give similar estimates of numbers of lost fish.

The numbers of channel catfish larvae killed show a general trend of increased impact across more southerly UMR pools. This pattern reflects both the longer navigation season and the greater traffic intensity. A similar pattern results for mortality expressed as a percentage of total larval production, although pool-specific differences in larval densities, duration of the spawning season, and traffic intensities can produce a pattern of percentage impacts somewhat different from that observed for number of larvae killed.

Over the course of the channel catfish spawning season, the values of conditional entrainment mortality ranged from 0.231 to 0.950. These results may emphasize some of the conservative assumptions made concerning the availability of larvae (e.g., the value of w_i in the model and the fact that each vessel per day encounters the same larval density), the fraction of entrained larvae killed (e.g., f_i), and estimates of entrainment rates developed in the exposure analysis. Future evaluation of these results will focus methods of numerical sensitivity on identifying the parameters that produced these very high rates.

Traffic Increase Scenarios

The results showing the projected impacts of percentage increases in commercial traffic on Pool 8 channel catfish are presented in Table 9. The results demonstrate that a percentage increase in traffic volume, without changing the nature of its seasonal distribution or associated fleet characteristics, produces a corresponding percentage increase in the number of larvae killed and their percentage of total larval production in the pool. The same relative impacts resulted for other fish species and other pools; the only factor that changed in the model was the scalar increase in the average number of vessels per day. The entrainment estimates are linear functions of the numbers of vessels per day.

For the traffic increase scenarios, CEM ranged from 0.954 (25 percent) to 0.991 (100 percent). Both the CEMs and the PF values are not simple linear multiples. The CEM rate will approach an asymptotic value of 1.0 as larval survival values become vanishingly small. The PF model represents a nonlinear extrapolation of killed larvae as a function of the species-specific differences between growth and mortality. Again, these initial results partially reflect some of the conservative assumptions underlying the assessment, as well as differences between how the fish assessment models extrapolate numbers of killed larvae or entrainment mortality rate. More detailed analysis of these results is the subject of continuing evaluation of applying these models to the Navigation Study Fish Ecological Risk Assessment.

Table 9
Projected Impacts of Increased Traffic on Channel Catfish in Pool 8 in July

	Larvae Killed	Percent of Pool Production	EAL #fish	RF #fish	PF tons
25 Percent Traffic Increase					
Mean	1,890,000	5.00	1,350	639	209
HQLS	3,150,000	8.32	2,260	1,060	346
LQHS	981,000	2.59	658	331	108
50 Percent Traffic Increase					
Mean	2,270,000	6.00	1,630	767	250
HQLS	3,780,000	9.99	2,720	1,280	415
LQHS	1,180,000	3.11	813	398	130
75 Percent Traffic Increase					
Mean	2,650,000	7.00	1,900	895	291
HQLS	4,410,000	11.7	3,170	1,490	483
LQHS	1,370,000	3.63	964	464	152
100 Percent Traffic Increase					
Mean	3,030,000	8.00	2,170	1,020	333
HQLS	5,040,000	13.3	3,620	1,700	551
LQHS	1,570,000	4.15	1,110	530	173

It is likely that future traffic projections based on the results of economic models and the dynamics of moving seasonal commodities through the system will result in impacts that are not simple linear multiples of baseline impacts. The larval fish entrainment models appear to have the capability to address these potential alterations in the distribution of seasonal traffic intensity.

Incremental Impacts

The incremental impacts of commercial navigation can be used to assess which species in which pools appear to be at greatest risk. Tables 10-15 summarize the incremental impacts of the traffic percentage increase scenarios for the six selected species. Depending on the species, the larval entrainment calculations suggest increased mortality ranging from ~100,000 (e.g., walleye) to 100,000,000 (e.g., emerald shiner, gizzard shad) individual larvae for Pool 13 in these peak spawning months. However, in terms of differences in mortality expressed as a percent of total larval production, the incremental impacts are ~0.008-2.69 percent; fairly similar percentage differences among several species

Table 10
Incremental Impacts of Increased Commercial Traffic on Emerald Shiner in UMR Pool 13 for the Month of July

	ΔLarvae Killed	ΔPercent	ΔEAL	ΔRF #fish	ΔPF tons
25 Percent Traffic Increase					
Mean	8,770,000	0.0435	135	113,000	0.250
HQLS	14,500,000	0.0717	315	186,000	0.379
LQHS	4,660,000	0.0231	42.8	59,800	0.141
50 Percent Traffic Increase					
Mean	17,500,000	0.0869	292	225,000	0.494
HQLS	28,900,000	0.143	668	372,000	0.740
LQHS	9,320,000	0.0462	93.4	120,000	0.281
75 Percent Traffic Increase					
Mean	26,700,000	0.132	475	343,000	0.741
HQLS	44,100,000	0.218	1,070	566,000	1.10
LQHS	14,200,000	0.0703	154	182,000	0.424
100 Percent Traffic Increase					
Mean	35,500,000	0.176	668	456,000	0.971
HQLS	58,500,000	0.290	1,480	752,000	1.43
LQHS	18,900,000	0.0934	220	242,000	0.559

Table 11
Incremental Impacts of Increased Commercial Traffic on Freshwater Drum in UMR Pool 13 for the Month of July

	ΔLarvae Killed	ΔPercent	ΔEAL	ΔRF #fish	ΔPF tons
25 Percent Traffic Increase					
Mean	862,000	0.0286	1.96	11.0	189
HQLS	1,420,000	0.0472	3.02	18.1	305
LQHS	458,000	0.0152	1.01	58.1	102
50 Percent Traffic Increase					
Mean	1,720,000	0.0572	3.87	21.9	376
HQLS	2,840,000	0.0943	5.98	36.1	606
LQHS	915,000	0.0304	2.04	11.6	203
75 Percent Traffic Increase					
Mean	2,630,000	0.0872	5.83	33.4	571
HQLS	4,330,000	0.144	9.03	55.0	918
LQHS	1,390,000	0.0463	3.14	17.7	309
100 Percent Traffic Increase					
Mean	3,490,000	0.116	7.66	44.3	756
HQLS	5,750,000	0.191	11.9	73.1	1,210
LQHS	1,850,000	0.0615	4.19	23.5	409

Table 12
Incremental Impacts of Increased Commercial Traffic on Mooneye in UMR Pool 13 for the Month of June

	ΔLarvae Killed	ΔPercent	ΔEAL	ΔRF #fish	ΔPF tons
25 Percent Traffic Increase					
Mean	242,000	0.204	155	111	8.42
HQLS	380,000	0.320	230	174	13.0
LQHS	142,000	0.120	95.0	64.9	4.98
50 Percent Traffic Increase					
Mean	484,000	0.408	306	222	16.8
HQLS	760,000	0.641	457	348	25.9
LQHS	284,000	0.239	190	130	9.95
75 Percent Traffic Increase					
Mean	716,000	0.604	448	328	24.8
HQLS	1,120,000	0.948	673	515	38.2
LQHS	420,000	0.345	279	192	14.7
100 Percent Traffic Increase					
Mean	959,000	0.808	594	439	33.0
HQLS	1,500,000	1.27	898	689	50.9
LQHS	562,000	0.473	370	257	19.6

Table 13
Incremental Impacts of Increased Commercial Traffic on Gizzard Shad in UMR Pool 13 for the Month of July

	ΔLarvae Killed	ΔPercent	ΔEAL #fish	ΔRF #fish	ΔPF tons
25 Percent Traffic Increase					
Mean	12,700,000	0.160	1,460	128	287
HQLS	21,000,000	0.264	2,250	210	471
LQHS	6,760,000	0.0850	768	67.8	153
50 Percent Traffic Increase					
Mean	25,500,000	0.320	2,880	255	573
HQLS	42,000,000	0.528	4,460	421	940
LQHS	13,500,000	0.170	1,550	136	306
75 Percent Traffic Increase					
Mean	38,800,000	0.488	4,340	389	873
HQLS	64,000,000	0.804	6,740	641	1,430
LQHS	20,600,000	0.259	2,380	207	466
100 Percent Traffic Increase					
Mean	51,500,000	0.648	5,700	517	1,160
HQLS	84,900,000	1.07	8,910	852	1,900
LQHS	27,400,000	0.344	3,170	274	618

Table 14
Incremental Impacts of Increased Commercial Traffic on Channel Catfish in UMR Pool 13 for the Month of July

	ΔLarvae Killed	ΔPercent	ΔEAL	ΔRF #fish	ΔPF tons
25 Percent Traffic Increase					
Mean	690,000	0.664	540	233	75.9
HQLS	1,140,000	1.10	836	384	125
LQHS	366,000	0.353	296	124	40.4
50 Percent Traffic Increase					
Mean	1,380,000	1.33	1,070	466	152
HQLS	2,270,000	2.19	1,660	768	249
LQHS	732,000	0.706	595	247	80.9
75 Percent Traffic Increase					
Mean	2,100,000	2.03	1,600	710	231
HQLS	3,470,000	3.34	2,520	1,170	379
LQHS	1,120,000	1.08	905	377	123
100 Percent Traffic Increase					
Mean	2,790,000	2.69	2,110	943	307
HQLS	4,600,000	4.43	3,340	1,550	503
LQHS	1,480,000	1.43	1,200	501	164

Table 15
Incremental Impacts of Increased Commercial Traffic on Walleye in UMR Pool 13 for the Month of June

	ΔLarvae Killed	ΔPercent	ΔEAL #fish	ΔRF #fish	ΔPF tons
25 Percent Traffic Increase					
Mean	30,300	0.00755	45.6	0.344	15.1
HQLS	47,500	0.0119	67.3	0.539	23.6
LQHS	17,700	0.00442	27.1	0.201	88.6
50 Percent Traffic Increase					
Mean	60,500	0.0151	90.0	0.687	30.1
HQLS	95,000	0.0237	133	1.08	47.1
LQHS	35,500	0.00884	54.4	0.402	17.7
75 Percent Traffic Increase					
Mean	89,600	0.0223	131	1.02	44.5
HQLS	141,000	0.0351	196	1.60	69.6
LQHS	52,500	0.0131	80.4	0.595	26.2
100 Percent Traffic Increase					
Mean	120,000	0.0299	174	1.36	59.5
HQLS	188,000	0.0469	260	2.13	93.0
LQHS	70,200	0.0175	107	0.796	35.0

for the same month reflect the proportional nature of the traffic increase, although the absolute numbers differ by orders of magnitude among these species. In absolute numbers, the impacts in Pool 13 appear greatest for gizzard shad and emerald shiner. Intermediate impacts in Pool 13 are demonstrated for freshwater drum, mooneye, and channel catfish. Walleye appear least impacted, although 30,300 additional larvae deaths (compared to the 1992 baseline) are estimated on average for a 25 percent traffic increase. The species-specific natural mortalities, growth rates, weights, and fecundities (Appendix A) translate the calculated larval mortalities into different estimates of lost future adults, lost recruits, and unrealized production of fish biomass.

Similarly, the impacts can be summed over the entire UMR-IWW System to develop a larger picture of the potential risks to each of the species of concern. The results of these rank-orders of potential impact might be used to design strategies to avoid or minimize impacts associated with more realistic future traffic scenarios. Table 16 makes such a comparison for the six selected species summarized in this section of the risk assessment. Using the RF model results for the 25 percent traffic increase scenario, the model calculations suggest that the emerald shiner is at greatest risk, with walleye suffering the smallest incremental

Table 16
Comparison of Incremental Impacts on Recruitment Forgone (Numbers of Fish) for Six Selected Fish Species in the UMR-IWW System Based on a 25 Percent Increase in Commercial Traffic

Range of RF Incremental Impacts	UMR	IWW	Total System
Emerald Shiner			
Mean	88,200,000	18,300,000	106,000,000
HQLS	141,000,000	28,200,000	169,000,000
LQHS	49,900,000	8,260,000	58,100,000
Freshwater Drum			
Mean	216,000	15,100	231,000
HQLS	347,000	23,500	370,000
LQHS	122,000	6,710	128,000
Mooneye			
Mean	60,400	1,910	62,300
HQLS	96,200	3,310	99,600
LQHS	34,300	908	35,200
Gizzard Shad			
Mean	46,800	37,700	84,500
HQLS	75,500	58,200	134,000
LQHS	26,000	17,100	43,000
Channel Catfish			
Mean	49,200	3,140	52,300
HQLS	80,600	4,880	85,500
LQHS	26,500	1,400	27,900
Walleye			
Mean	1,420	16.6	1,430
HQLS	2,280	25.7	2,310
LQHS	788	7.50	796

increase in lost future recruits as a result of increased larval mortality. For gizzard shad, the impacts are comparatively similar for the UMR and IWW. For the remaining species, the relatively larger UMR contribution to total lost recruits appears to reflect the larger size of the UMR.

Uncertainties

One key aspect of ecological risk assessment that distinguishes this process from more historical environmental assessments performed under the National Environmental Policy Act is the explicit identification and quantification of uncertainties that enter into the analysis. Once quantified, these uncertainties are included in the assessment calculations to produce probabilistic estimates of ecological impacts (i.e., risks). In the Navigation Study Fish Ecological Risk Assessment, uncertainties enter the analysis in the form of bias and imprecision in the estimates of future traffic intensity, in the characterization of entrainment volumes generated by specific vessel configurations, and in the parameters input into the ecological models. Uncertainties also take the form of the simplifications and assumptions that are inherent in the modeling process.

A future important aspect of this risk assessment process will be application of numerical methods to identify and rank-order the contributions of specific sources of uncertainty to the overall assessment results. Such analyses can be used to design additional studies or identify additional data collection that will provide the greatest return in reducing bias and imprecision per unit investment of future Navigation Study resources.

Verification and Evaluation of Estimated Larval Entrainment

Preliminary results of applying the larval entrainment model and the subsequent extrapolation models to assess the potential impacts of increased commercial traffic on fishes in the UMR-IWW System are summarized in the previous tables and presented in their entirety in Appendix E. Verification and evaluation of these results are important objectives in the continued development of these methods for the forthcoming economics-based traffic projections. In part, the verification process included repeated calculations for selected scenarios to determine if the models have been correctly implemented in computer code (i.e., FORTRAN). For example, setting the standard deviations assigned to Q_p and S to zero correctly produced identical results for the mean, HQLS, and LQHS calculations throughout. With few exceptions that remain the focus of additional analysis, the HQLS and LQHS estimates bracketed the mean values across all calculations, as expected. As discussed previously, the 25, 50, 75, and 100 percent increases in larval entrainment calculated for the corresponding percent increases in traffic also verify the model. At the same time, several of the PF calculations appear inconsistent with the associated number of entrained larvae. These calculations are being further verified to identify the reason for the inconsistency and to correct any remaining errors in coding. Additional verification tests are being designed to provide a thorough testing of the model code prior to assessing the more realistic traffic scenarios.

Data that quantify the entrainment of fish larvae by electric generating facilities (i.e., power plants) located throughout the UMR-IWW System are being collated for comparison (e.g., Appendix C) with the estimated commercial traffic-induced mortality estimates. While it is recognized that the nature of entrainment differs fundamentally between the spatially fixed power plants and the navigating traffic, the power plant entrainment data might nevertheless point out gross discrepancies between the estimated commercial traffic entrainment calculations and observations for power plants on the UMR-IWW System. Depending on the credibility of the navigation entrainment results, the power plant data might also be used to provide some context for assessing the comparative significance of traffic-induced larval mortality (i.e., "power-plant equivalents"). For example, Jensen (1990) estimated entrainment of approximately 128,000,000 yellow perch larvae by the Monroe Power Plant, located on the western basin of Lake Erie. He used the RF model to estimate a corresponding loss of 8,900 future recruits. Jensen's power plant entrainment values compare with the range of 100,000-1,000,000,000 larvae entrained by commercial traffic. His estimate of lost perch recruits compares to the 10-10,000,000 incremental increases in lost recruits estimated for the six species in the UMR-IWW (Tables 10-15). Jensen et al. (1988) estimated power plant impacts on gizzard shad production forgone as 570 metric tons (570,000 kg). This magnitude is similar to the magnitudes of incremental impacts on gizzard shad production estimated for a 50 percent increase in commercial traffic for Pool 13 in this initial assessment (e.g., Table 13). If the entrainment rate for a given power plant is known and values of w_i and f_i for power plant entrainment are assumed, it might also prove possible to calibrate the w_i factor for various species and corresponding pools addressed by the navigation assessment entrainment model.

Commercial fisheries data compiled annually by the UMRCC from the five UMR states of Illinois, Wisconsin, Minnesota, Iowa, and Missouri, despite their well-recognized shortcomings, collated for several species in the UMR-IWW System (Appendix D) might also prove useful for evaluating the larval entrainment calculations, or more exactly, the extrapolation of these values to lost future recruits or biomass. For example, the estimates of navigation-induced production forgone for commercially fished species can be readily compared with commercial catch data after converting the catch data from pounds to metric tons. After an average weight for individual commercially harvested species (e.g., weight at recruitment) is derived, the commercial catch data can be translated into numbers of fish to compare with estimates of recruits lost to larval entrainment. As with the power plant entrainment data, these comparisons may prove useful in evaluating the credibility of the larval entrainment estimates for commercial navigation. Significance of estimated lost recruits or lost biomass might also be estimated in relation to the historical catch data.

The preceding activities are the foci of continued efforts aimed at verifying, evaluating, and refining the Navigation Study Fish Ecological Risk Assessment for the UMR-IWW System.